SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, YOSHIHIRO NONOGAKI, a
citizen of Japan residing at Handa-Shi, Aichi, Japan and
TAKAO ASABA, a citizen of Japan residing at Ota-Ku, Tokyo,
Japan have invented certain new and useful improvements in

A METHOD FOR GENERATING A FORMULA FOR CALCULATING
MOTTLING OF A PAINT FILM, AND A QUANTIFICATION METHOD
OF THE MOTTLING

of which the following is a specification:-

TITLE OF THE INVENTION

A METHOD FOR GENERATING A FORMULA FOR CALCULATING MOTTLING OF A PAINT FILM, AND A QUANTIFICATION METHOD OF THE MOTTLING

BACKGROUND OF THE INVENTION

The present invention generally relates to a method for generating a formula for calculating mottling of a paint film, and a quantification method of the mottling.

It is practiced that colors are blended such that a color desired by a user is obtained. At that time, success or failure of blending is determined by evaluating performance such as paint finish performance, paint film performance, and paint material performance of an actually blended paint. However, user preference is highly diversified, and the number of colors required by users can be as great as the number of the users. For this reason, past data are often inapplicable, and testing of each color is required, resulting in the need for a large amount of manpower and time.

Under situations as described above, it is highly desired that a calculation formula (prediction formula) be established such that performance of a blended paint is predicted, and only a successful blending is provided to the users.

In order to determine successful blending without performance problems, information about performance, such as the paint finish performance, the paint film performance, and the paint material performance, is quantified and evaluated based on past actual results, etc. Here, the paint finish performance is related to skin, gloss, mottling, sagging, pinholes, workability to a production line, etc; the paint film performance is related to

durability (degree of degradation due to the sunlight), corrosion resistance (degree of degradation due to rust and water), adhesion, chipping nature, hardness, electric resistance,
5   gloss, chemical resistance, etc.; and the paint material performance is related to storage durability, dilution stability, circulation-proof nature, etc.

In this manner, the performance of a
10   blended paint is predictable, and whether an acceptable quality of the paint is obtainable can be determined using the information described above, and the problem about time and effort is solved.

However, in the case that a paint contains
15   glittering color material (such as metal flakes, and pearlescent mica), the color of the paint changes with viewing angle, and evaluation of the mottling is especially difficult.

In this connection, JP, 5-288690,A(patent
20   reference 1) discloses "A paint mottling determination method of a metallic paint film", wherein by an irradiation process, a laser light having a beam diameter of 5-to-10 mm is irradiated to the surface of a target (to be measured) paint
25   film of a metallic paint, and the laser light is irradiated at a predetermined angle of incidence, and by a light-receiving process, the laser light reflected by the target paint film is received. The irradiation process and the light-receiving process
30   are carried out at two or more contiguous spots that are apart from each other by a distance equal to or less than the laser beam diameter, and optical brightness of the reflected light that is received is calculated at two or more predetermined
35   wavelengths, which process is repeated for all the spots. According to the optical brightness at the predetermined wavelengths of all the spots, the

degree of paint mottling is determined.

Further, JP, 9-318448,A(patent reference 2) discloses "A mottling determination apparatus and an evaluation method of metallic paints" wherein a light is irradiated to a target paint surface, the brightness of the reflected light is continually measured, the reflected light being received at angles at which mirror reflection light is not received (i.e., the specularly reflected light being excepted), and a degree of mottling of the surface of the target paint is determined by calculating (1) the difference between the brightness of the received light that exceeds an average of the measured brightness by a predetermined amount, and the brightness that is less than the average of the measured brightness by the predetermined amount, and (2) the distance between a spot that gives the brightness that exceeds the average by the predetermined amount, and a spot that gives the brightness that is less than the average by the predetermined amount.

Nevertheless, according to the inventions disclosed by the patent references 1 and 2 presented above, the amount of reflected light is measured only along a predetermined line on the paint film, and only the brightness is considered in determining the mottling. For this reason, precision of the mottling determination is not sufficient. In other words, the mottling, which essentially is a two-dimensional object, is determined based only on measurement data along a line (one dimension), and only the brightness, and the mottling of the surface in two dimensions cannot be properly determined.

SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a method for generating a calculation formula of the paint mottling based on two-dimensional data and color values of a target

5 paint film surface to obtain an accurate representation of the paint mottling, and a quantification method for quantifying (expressing in numerical terms) the paint mottling, the formula generating method and the quantification method

10 substantially obviating one or more of the problems caused by the limitations and disadvantages of the related art.

Features and advantages of the present invention are set forth in the description that

15 follows, and in part will become apparent from the description and the accompanying drawings, or may be learned by practice of the invention according to the teachings provided in the description. Objects as well as other features and advantages of the

20 present invention will be realized and attained by the methods particularly pointed out in the specification in such full, clear, concise, and exact terms as to enable a person having ordinary skill in the art to practice the invention.

25 To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention provides an image generating step for generating a two-dimensional brightness image of a target paint

30 film; a glitter representing value calculating step for calculating a glitter representing value from the two-dimensional brightness image; a color value acquisition step for obtaining color values of a reflected light of an incident light received at

35 predetermined viewing angles to the target paint film; a visual evaluation value acquisition step for obtaining a visual evaluation value of the paint

mottling of the target paint film; and an mottling calculating step for obtaining a formula for calculating the paint mottling based on the glitter representing value, the color values and the visual

5   evaluation value. In this manner, the paint mottling calculated by the calculation formula generated according to the present invention is precise, because the method considers two-dimensional data (not just data along a one-dimensional line), and

10 the color data (in addition to brightness data).

An aspect of the present invention is characterized by an image pick-up apparatus, such as a scanner and a CCD camera, being used in the image generating step such that an image suitable for the

15 target paint surface is obtained.

An aspect of the present invention is characterized by the glitter representing value calculating step including an image processing step for processing the brightness image using a spatial-

20 frequency differential process, and a total calculating step for obtaining a total of gradation steps of the brightness image that is processed at the image processing step. In this manner, the glitter representing value is easily obtained.

25   An aspect of the present invention is characterized by the spatial-frequency differential process using one of a Sobel filter, a Roberts filter, and a Laplacian filter. In this manner, the glitter representing value can be obtained by using

30 commercial software.

An aspect of the present invention is characterized by the color value acquisition step obtaining at least one of a chroma value, an FF value thereof, a brightness value, an FF value

35 thereof at the predetermined light-receiving angles, a hue angle at the above-mentioned predetermined angles, and a hue angle difference. In this manner,

a paint mottling value can be obtained using a selection of color values that is suitable for the target paint film.

An aspect of the present invention is
5 characterized by generating the formula for calculating mottling using QSAR analysis software. In this manner, by using a sample painted panel provided by a customer, a formula for calculating mottling that has correlations suitable for the
10 customer, and a mottling value suitable for the customer can be obtained.

The present invention also provides a quantification method for quantifying the paint mottling of the target paint film based on the color
15 values and data in two dimensions.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flowchart showing a process
20 for generating a formula for calculating mottling of a paint film;

Fig. 2 is a chart for explaining a hue angle calculation;

Fig. 3 is a flowchart showing a process
25 for calculating the paint film mottling;

Fig. 4 is a table showing pigment compositions (pwc);

Fig. 5 shows painting conditions;

Fig. 6 is a table showing an example of
30 colorimetric values and color values of paint films;

Fig. 7 shows an example of QSAR analysis results; and

Fig. 8 graphs correlations between visual mottling and calculated mottling.
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DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, embodiments of the present invention are described with reference to the accompanying drawings.

(Generating a formula for calculating paint film mottling)

Fig. 1 shows a process for generating a formula for calculating paint film mottling wherein target painted panels are prepared and evaluated at step S10, glitter representing values are calculated at step S11, colorimetric values are measured at step S12, and the formula for calculating the paint film mottling is obtained at step S13. Here, the steps S11 and S12 do not have to be in this sequence, but may be performed in the reverse sequence, or may be simultaneously processed.

At step S10 wherein the target painted panels are prepared and evaluated, the following process is carried out.

(1) Two or more paints using various glittering materials and pigments are prepared. The larger the number of different paints that are prepared, the higher the correlation of the formula to visible mottling can be obtained.

(2) The paints are applied to the panels such that a paint film is formed on the painted panels. When painting the panels, two or more panels are painted with the same paint, but with different spraying conditions, which painting is repeated for all the prepared paints.

(3) The dimensions of the panels prepared are desired to be 300x400 mm or larger such that visual evaluation of mottling is facilitated.

Then, visual evaluation of the panels prepared as above is performed.

Step S11 wherein the glitter representing value is calculated includes image measurement step S11a that further includes image inputting step

S11a1, and image processing step S11a2. Step S11a
can be replaced with brightness measurement step
S11b as described later.

The image inputting step S11a1 takes in
images of the paint film of the painted panels
prepared at step S10 using an image taking apparatus
such as a scanner, a CCD camera, and an image pick-
up apparatus with appropriate software. Then, the
images are saved with suitable file names attached.

At the image processing step S11a2, a
suitable pretreatment, such as noise removal, is
performed, and then pseudo-glitter (simulated
glitter) of the glittering material is extracted
using image-processing software that is capable of
extracting the glitter of the image taken in at the
image inputting step S11a1. Subsequently, the
glitter representing value of the obtained image is
computed.

Here, as image-processing software that is
capable of extracting glitter after the pretreatment,
one of a Sobel filter, a Roberts filter, and a
Laplacian filter, etc., that performs spatial-
frequency differential processing is used.

The glitter representing value is
calculated as follows, for example.

(1) Gradation step values are totaled, and
the sum is used as the glitter representing value,
the gradation step values being those of the image
on which the spatial-frequency differential
processing is performed.

(2) After a suitable pretreatment, such as
noise removal, a gradation step value that has the
maximum frequency (the number of occurrences is the
greatest) is made to be the glitter representing
value, the gradation step value excepting the white
value and the black value.

Alternatively, the glitter representing

value calculation step S11 can use the brightness
measurement step S11b. At S11b, pseudo-glitter of
the glittering material is extracted from the amount
of the received reflection light at angles at which
5   a mirror reflection light is not received (i.e., the
specularly reflected light is excepted) using a
method for continuously measuring the brightness of
the surface of a paint film; for example, a glitter
measuring instrument ALCOPE made by Kansai Paint
10   Engineering, Ltd. can be used, the reflection light
being the reflection of a light irradiated to the
target painted panels that are prepared at step S10.
         After step S11, the process proceeds to
step S12 for processing color value measurement that
15   includes colorimetry step S121, and color value
calculation step S122.
         At the colorimetry step S121, the paint
film of the painted panels prepared at step S10 is
measured using a variable angle color meter (a
20   colorimeter), and colorimetric values are obtained.
Measurement conditions are the incident-light angle
being set at 45 degrees, light-receiving angles
being set at 15 degrees, 25 degrees, 45 degrees, 75
degrees, and 110 degrees. At this time, CIELAB is
25   used as the color coordinate system in this example.
         Then, the color value calculation process
at step S122 is performed using the colorimetric
values obtained at step S121. Here, the color values
to be used are L*, a*, and b* values measured at 15,
30   25, 45, 75, and 110 degrees, and values calculated
therefrom (refer to Fig. 6).
         Based on the colorimetric values measured
at step S121, each color value is calculated at step
S122 according to the following formulae.
35   a. C* value at 15 degrees =(15 degree
$(a*)^2+15$ degree$(b*)^2)^{0.5}$
         b. C* value at 25 degrees =(25 degree

$(a^*)^2 + 25$ degree$(b^*)^2)^{0.5}$

    c. C* value at 45 degrees $= (45$ degree $(a^*)^2 + 45$ degree$(b^*)^2)^{0.5}$

    d. C* value at 75 degrees $= (75$ degree $(a^*)^2 + 75$ degree$(b^*)^2)^{0.5}$

    e. C* value at 110 degrees $= (110$ degree $(a^*)^2 + 110$ degree$(b^*)^2)^{0.5}$

    f. C* value FF= (C* value at 15 degree – C* value at 110 degrees)

    g. hue angle difference [hue angle at 15 degrees – hue angle at 110 degrees] = (15 degree hue angle) – (110-degree hue angle)

    h. 15 degree hue angle

    i. 25 degree hue angle

    j. 45 degree hue angle

    k. 75 degree hue angle

    l. 110 degree hue angle

    m. Brightness FF= (L* value at 15 degrees – L* value at 110 degrees)

Here, a hue angle is calculated as follows depending on to which quadrant the hue angle belongs (refer to Fig. 2 showing a*-b* plane.)

The hue angle in the 1st quadrant is expressed by $\tan^{-1}(b^*/a^*)$.

The hue angle in the 2nd quadrant is expressed by $\tan^{-1}(-a^*/b^*) + 90$ degrees.

The hue angle in the 3rd quadrant is expressed by $\tan^{-1}(b^*/a^*) + 180$ degrees.

The hue angle in the 4th quadrant is expressed by $\tan^{-1}(a^*/-b^*) + 270$ degrees.

Following the color value measurement step S12, the paint film mottling calculation formula is generate at step S13.

Since the mottling is dependent on psychophysical values, such as glitter and hue, a correlation formula between the visual mottling and the psychophysical values obtained by measurements

is to be established. This is the difference of the
present invention using psychophysical values from
conventional practices considering only physical
values, such as the brightness of the reflective
light. In other words, since visual mottling is not
a physical value but a psychophysical value, the
present invention aims at obtaining correspondence
of visually measured mottling values to calculated
mottling values by defining a correlation formula
wherein the psychophysical values and the visual
mottling are considered.

In the present invention, the formula for
calculating paint film mottling is obtained as
follows.

(1) First, a visual mottling value y is
defined as a function of factors x_1 through x_n. Here,
as the factors x_1 through x_n, the glitter
representing value acquired at the glitter
representing value calculation step S11, the
colorimetric values acquired at the colorimetry step
S121, and the color values acquired at the color
value calculation step S122 are used (refer to Fig.
6).

(2) A table listing y, and x_1 through x_n,
such as shown by Fig. 6, is generated.

(3) Using QSAR analysis software, the
table described as above (2), which lists the
results and the factors, is analyzed, and a
correlation formula is obtained, wherein factors x_i
that give high correlation to y are selectively used,
as shown by Fig. 7.

(4) In this manner, the mottling of the
paint films is numerically expressed (i.e.,
quantified) using the correlation formula.

(5) The correlation formula varies with
kinds of data (properties of the paint film) to be
used for analysis, and factors for analysis.

Therefore, by using painted panels provided by a customer, correlation formulas suitable for the customer can be generated.

Further, an mottling value that meets the requirement of the customer can be calculated by using the correlation formula.

(Application of the correlation formula)

In the following, a method for obtaining the paint film mottling using the formula that is obtained as described above is explained.

In reference to Fig. 3, sample painted panels are prepared at step S20, the glitter representing value is calculated at step S21, the color values are obtained at step S22, and the obtained values are substituted in the correlation formula at step S23. Here, the sequence of steps S21 and S22 can be reversed, or alternatively, steps S21 and S22 may be simultaneously processed.

At step S20, the sample painted panels are prepared with various glittering materials, and pigments. Painting conditions are the same as described for step S10.

At step S21, the glitter representing value is calculated by the same method as described for step S11.

At step S22, the colorimetric values are measured by the same method as described for step S12 using a variable angle colorimeter, and the color values are calculated from the colorimetric values.

At step S23, the glitter representing value acquired at step S21, and the color values acquired at step S22 are substituted in the correlation formula obtained at step S13, and the mottling value of the target paint film is obtained.

In addition, in the present invention, instead of actually preparing sample painted panels,

the glitter representing value and the color values
of a paint combination can be estimated from paints
to be mixed and glittering material information, and
applied to the correlation formula such that an
5   estimated film mottling value of the paint
combination is predicted.

Further, although the glitter representing
value and the color values of the sample painted
panels are applied to the correlation formula, the
10   glitter representing value and the color values of
an actual item, such as a car, can be applied.

[Example]

Next, the embodiments of the present
invention that were actually experimented with are
15   explained referring to the attached drawings.

(A. Preparing painted panels)

(1) Preparing paints for map generation

About 80 different waterborne paints for
automobiles 2-coat 1-bake were prepared, pigment
20   composition (pwc) of which was 10 parts of an
acrylic resin, 30 parts of a melamine resin, and 40
parts of a urethane system emulsion. Fig. 4 shows
seven paints selected from the "about 80 paints",
the seven paints being identified by A020001,
25   A020002, A020005, A020007, A020008, A020009 and
A020010, respectively.

(2) Painting

The paints prepared at (1) above were
applied to panels using a bell type paint machine
30   "ABB1N1072F" made by ABB under conditions described
in Fig. 5. The panels were prepared in dimensions of
300 mm x 400 mm; and electrodeposition for cars and
middle coating were applied to the panels. The
panels were preheated at 80 degrees C for 3 minutes;
35   a top clear coat was painted on the panels; and
baking was performed on the panels at 140 degrees C
for 30 minutes.

Here, the painting included two base coating steps, with a 90 second interval in-between.

(B. Measurement of the glitter representing value)

5 The glitter representing value was determined as follows.

(1) Taking in of an image

Image taking-in software and a flat bed scanner (Canoscan D2400U) were used to take in the

10 image of the painted panels prepared above (at A. Preparing paint film) to a personal computer as bit map data having resolution of 300 dpi and a 256-step gray scale.

(2) Image processing

15 Using image-processing software (Adobe Photoshop), both edges containing a large amount of noise were removed from the image that was taken in above (at B. (1) Taking in of an image), then a Sobel filter was applied. After a post-treatment,

20 the image was quantified (made to be numerically expressed) based on the frequency of edge detection and the like, and the numerical value was made to serve as the glitter representing value.

(C. Measurement of color values)

25 Colorimetric values of the painted panels were obtained using MA-68II (Portable Multi-Angle Spectrophotometer) made by X-Rite. The color coordinate system of CIELAB was used.

MA-68II is a multi-angle spectrophotometer

30 capable of aspecular measurements of L*a*b*, $\Delta L^* \Delta a^* \Delta b^*$, L*C*h degrees, ΔL^*, ΔC^*, ΔH^*, a flop index, Δflop index, and so on. Further, the spectrophotometer has a 45-degree illumination, enabling measurements at 15, 25, 45, 75, and 110

35 degrees.

Using the colorimetric values obtained as above, color values described at the step S122

(color value calculation step) were calculated.

(D. mottling visual evaluation)

Mottling of the panels prepared at "preparing painted panels" was visually evaluated, and a visual mottling value was determined.

(E. Calculation of a correlation formula)

Then, the correlation formula was generated using QSAR analysis software (Cerius2 made by Accelrys) with the visual mottling value serving as an objective variable, and the glitter representing value, the colorimetric values, and the color values being the variables.

Fig. 6 tables the glitter representing value, the visual mottling value, the colorimetric values, and the color values of painted panels having IDs "A020023" through "A020038".

An example of the QSAR analysis is shown in Fig. 7, where 10 correlation formulae and respective parameters that contribute to each of the correlation formulas are shown. There, X1 represents the chroma saturation (C*) at 45 degree light-receiving angle, X2 represents the glitter representing value, X3 represents L* at 15 degree light-receiving angle, X4 represents the brightness FF (i.e., 15 degree L* value -110 degree L* value), X5 represents the hue angle FF (i.e., 15 degree hue angle - 110 degree hue angle), X6 represents the chroma saturation FF (i.e., 15 degree C* value - 110 degree C* value), X7 represents the hue angles at 45 degree light-receiving angle, and y represents the visual mottling.

From the QSAR analysis results, an mottling calculation formula that gives the highest correlation to the visual mottling (serving as an objective variable) was made the mottling value calculation formula y. The correlation formula given in the first line of Fig. 7 was adopted, which was

generalized as follows.

$$y = A + bX1^2 + cXa2 + dX2a + eX2b + fX3a + gX4a \ \ldots \text{Formula (1)}$$

Here, the variables are as follows.

y: mottling value

X1= 45 degree C* value,

X2= glitter representing value

X3= 15 degree L* value

X4= brightness FF value (15 degree L* value - 110 degree L* value)

X1a=(2.25-X1)

X2a=(X2-97.0)

X2b=(X2-90.0)

X3a=(103.37-X3)

X4a=(52.36-X4)

Here, as for X1a, X2a, X2b, X3a, and X4a, if the value is less than "0", the value is made to be "0".

That is, X1a is valid when X1 is less than 2.25, X2a is valid when X2 exceeds 97, X2b is valid when X2 exceeds 90, X3a is valid when X3 is less than 103.37, and X4a is valid when X4 is less than 52.36.

Further, a through g are constants having values as follows.

a=3.35962   b=0.000474   c=0.11361
d=0.057642 e=-0.064096 f=-0.006376 g=0.000767

Here, the correlation coefficient R of the visual mottling value to the mottling value according to Formula (1) was 0.885.

Fig. 8 shows the correlation of the visual mottling values to the calculated mottling values obtained using the correlation formula (1). As seen from Fig. 8, the correlation formula (1) gives high correlations to the visual mottling values, and proves to be a reliable tool.

(F. Application of the mottling formula)

The mottling values of actual painted

panels were calculated using the formula (1), and the results are explained in the following.

(1) Preparing a sample paint

A waterborne paint for automobiles 2-coat
1-bake consisting of 10 parts of an acrylic resin, 30 parts of a melamine resin, and 40 parts of a urethane system emulsion was prepared with pigment composition (PWC) of:

- Aluminum flake pigment A   5.3
- Carbon black pigment A   1.8
- Organic blue pigment A   7.2
- Total   14.3.

(2) Preparing painted panels

The paint prepared at (1) above was applied to panels using a bell type paint machine "ABB1N1072F" made by ABB under conditions described in Fig. 5. The panels were prepared in dimensions of 300 mm x 400 mm; and electrodeposition for cars and middle coating were applied to the panels. The panels were preheated at 80 degrees C for 3 minutes; a top clear coat was painted on the panels; and baking was performed on the panels at 140 degrees C for 30 minutes.

(3) Taking in an image

Image taking-in software and a flat bed scanner were used to take in an image of the painted panel prepared in (2) above as bit map data to a personal computer at a resolution of 300 dpi in 256 gray-scale steps.

(4) Image processing

Using image-processing software (Adobe Photoshop), both edges containing a large amount of noise were removed from the image that was taken in above (at (3) Taking in an image), then a Sobel filter was applied. After a post-treatment, the glitter representing value was obtained.

(5) Measurement of color values

Colorimetric values of the painted panel were obtained using MA-68II (Portable Multi-Angle Spectrophotometer) made by X-Rite. The color coordinate system of CIELAB was used.

5   The color values were calculated using the colorimetric values, the color values having been explained at step S122 (color value calculation step) above.

Here, the painted panel identified as

10   "A020025" in Fig. 6 was used.

(6) Calculation of the mottling value

Substituting the above-mentioned values in the mottling calculation formula (1), the mottling value was computed.

15   Here, values of X1 through X4a were as follows.

X1=4.74 X2=235   X3=126.29   X4=110.21
X1a=0 X2a=138   X2b=145   X3a=0
X4a=0

20   The mottling value y was calculated as y=2.03, which sufficiently compares with the visual mottling value 2 of the painted panel "A020025".

In this manner, an mottling value almost equal to the visual evaluation was acquired by

25   calculation.

Since the color values of the target paint film were used according to the present invention, the mottling of the paint film was accurately determined by calculation.

30   As described above, according to the present invention, the method for obtaining the paint film mottling calculation formula, and the method for quantifying the paint film mottling that give accurate paint film mottling values are

35   provided, using two-dimensional data and color values of the target paint film.

Further, the present invention is not

limited to these embodiments, but various variations and modifications may be made without departing from the scope of the present invention.

5   The present application is based on Japanese Priority Application No.2003-096128 filed on March 31, 2003 with the Japanese Patent Office, the entire contents of which are hereby incorporated by reference.